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(54) Abstract Title

Pressure modulation valve assembly for use in combination with a downhole drilling motor and drillstring thruster

(57) A drillstring pressure modulation valve assembly comprises a spring 22 which bears against a compensation piston 76 at one end and on the other end against a modulating ram needle 27. The pressure modulation valve assembly (A, figure 1b) is situated between a pressure responsive thruster (34, figure 1a) and a fluid-operated drilling motor (50, figure 1c) attached to a drill bit (40, figure 1c). The thruster is responsive to internal pressure differences between itself and the annulus. The thruster acts by telescoping to add to the weight on bit (WOB) thus advancing drilling. Changes in conditions during drilling cause a pressure drop to occur through the drilling motor which increases pressure in the thruster. This causes positive feedback which advances the drill further and may stall the bit or motor. The modulation valve compensates for such changes to minimise the effect of such changes on the operation of the thruster. Piston 76 can be preloaded, with fluid flowing, before drilling commences. Spring-loaded needle 27 reacts to any pressure changes by varying the pressure difference at orifice 31.

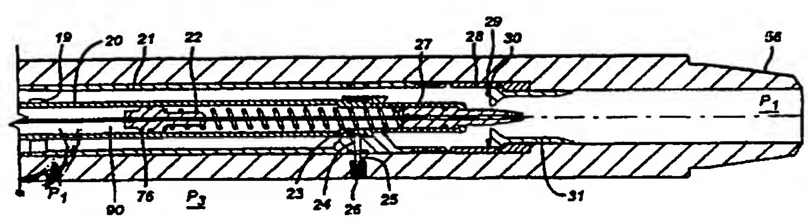

FIG. 3b

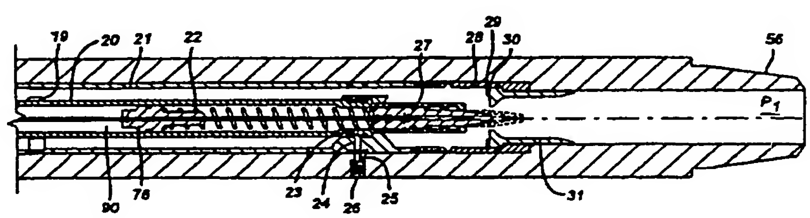

FIG. 4b

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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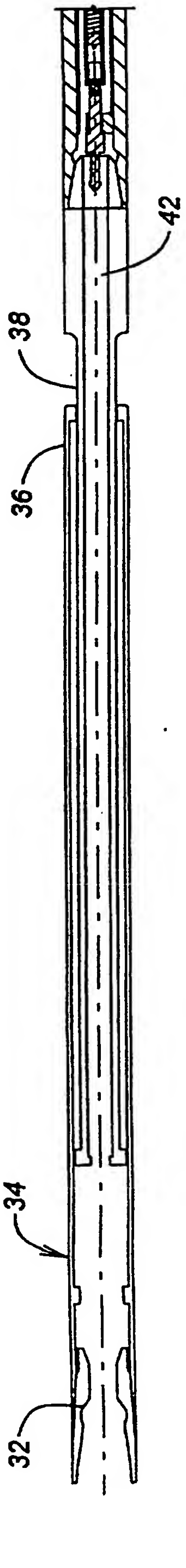

FIG. 1a

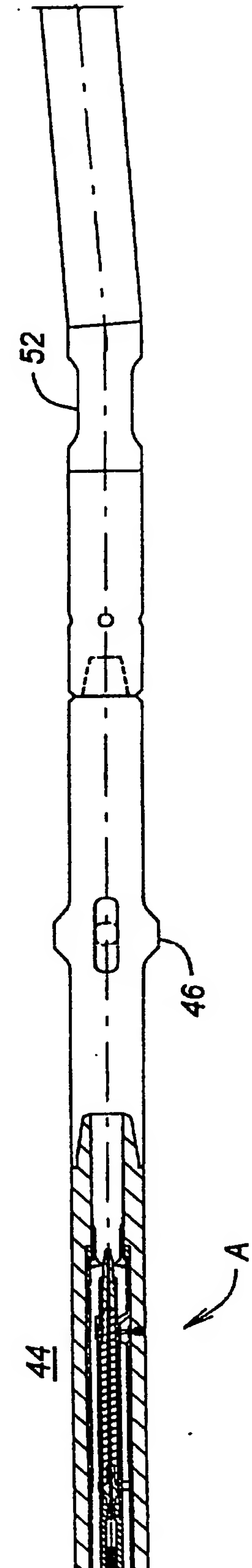

FIG. 1b

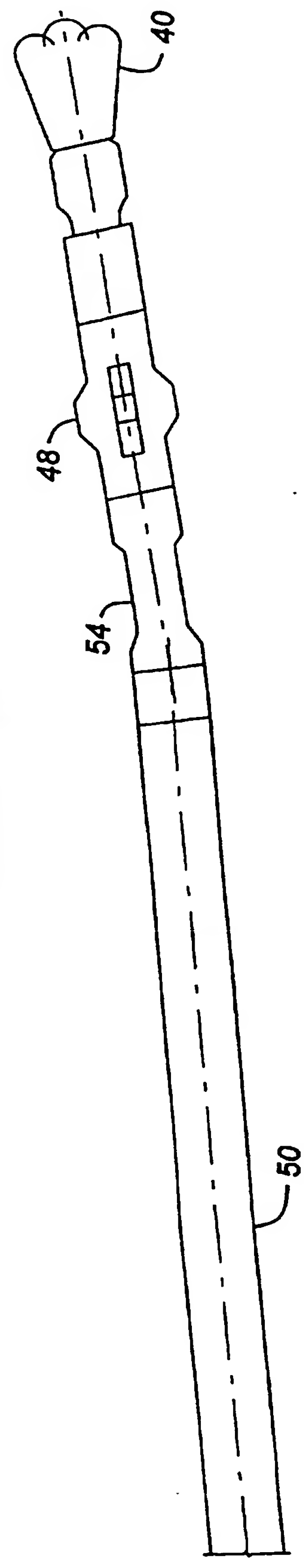

FIG. 1c

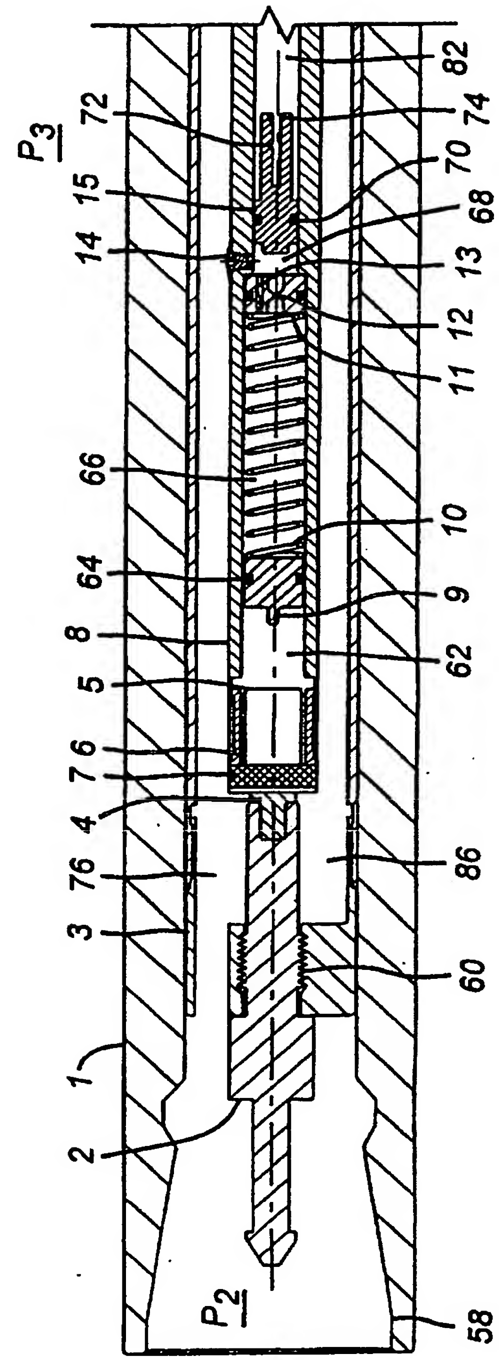

FIG. 2a

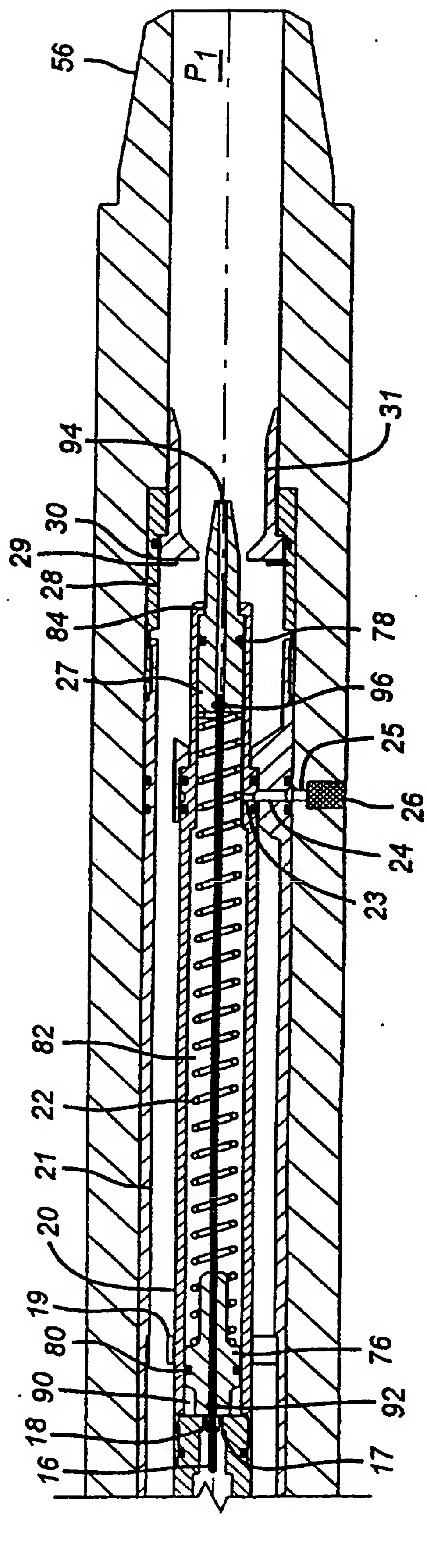
56
P_1
94
31
30
29
28
84
78
27
96
25
26
24
23
82
22
21
20
19
80
76
90
92
18
17
16

FIG. 2b

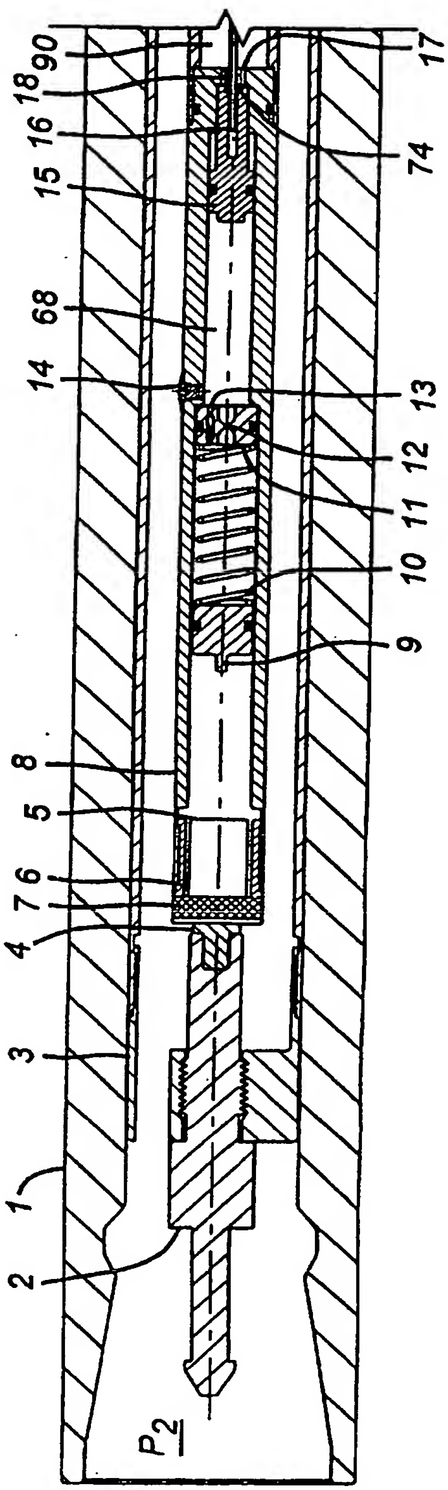

FIG. 3a

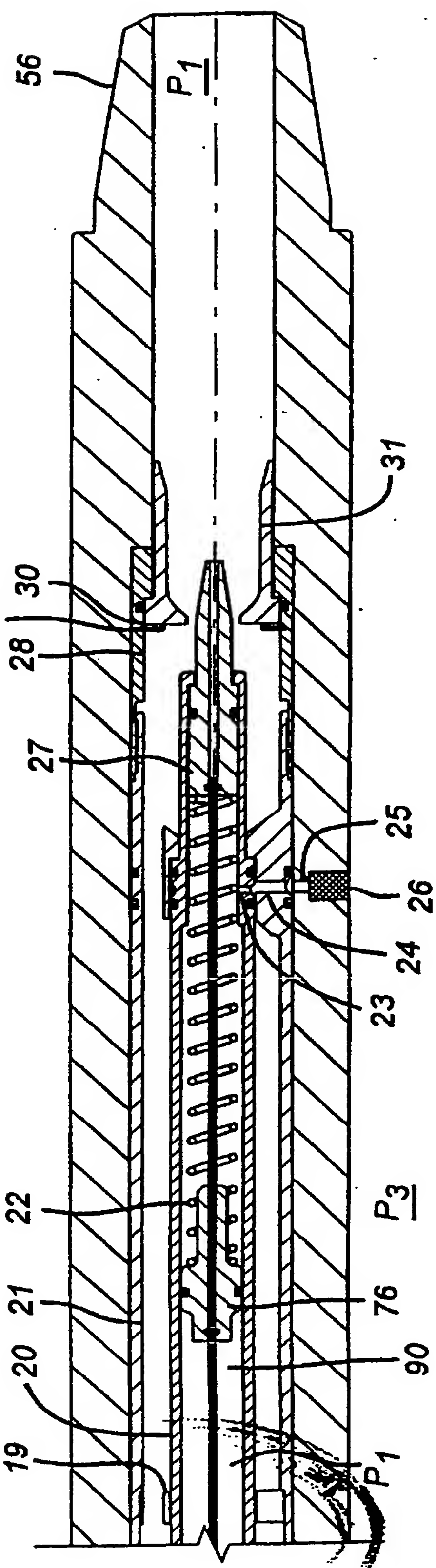

FIG. 3b

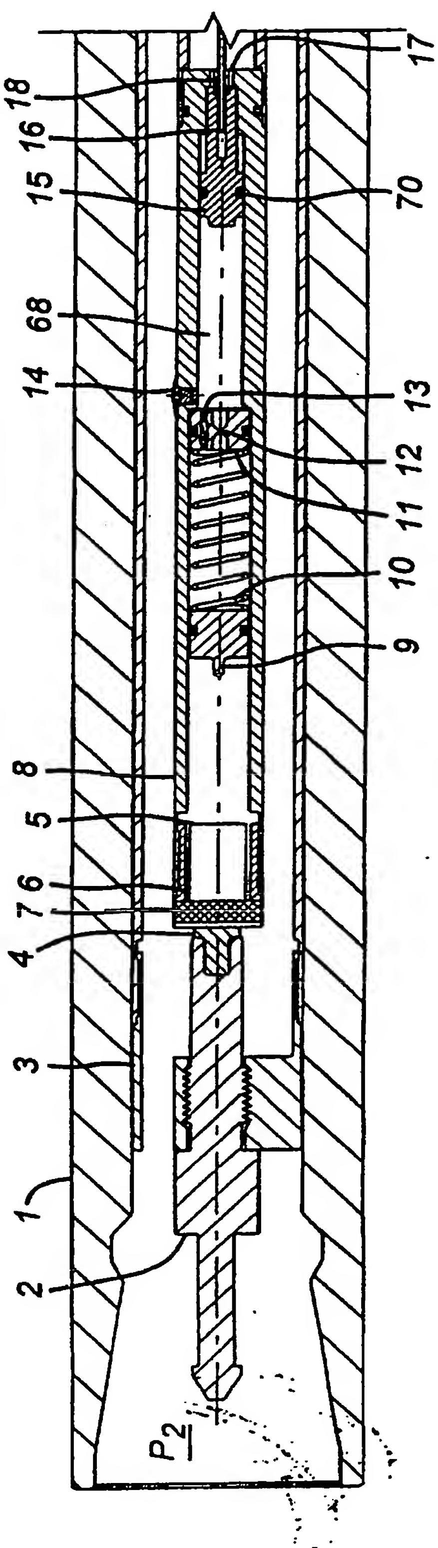

FIG. 4a

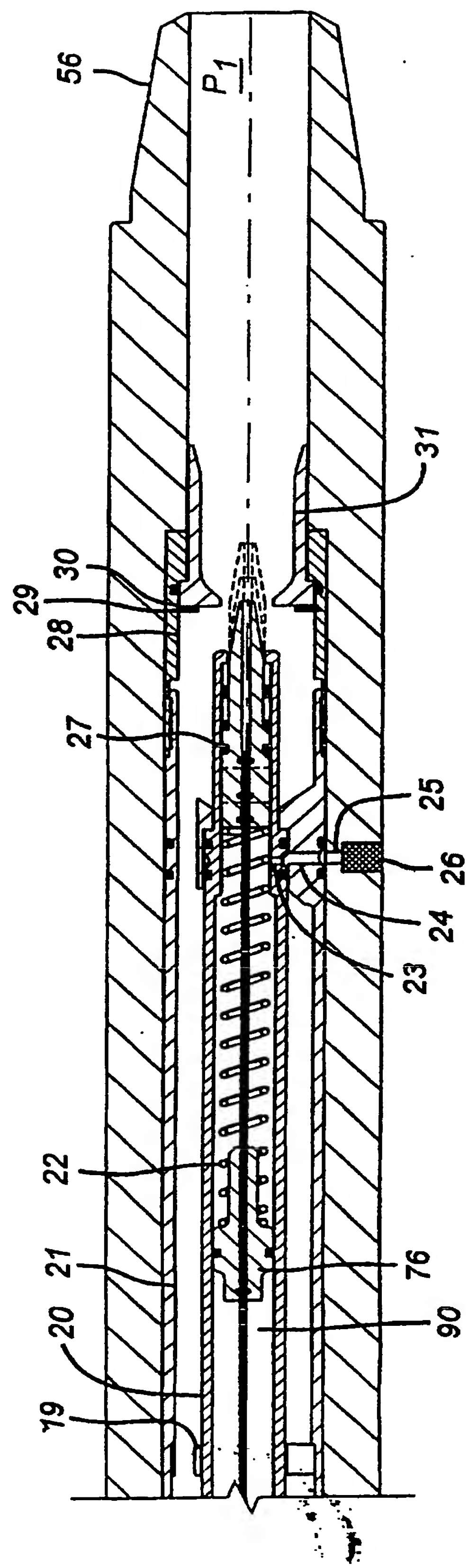

FIG. 4b

PRESSURE MODULATION VALVE ASSEMBLY

The field of this invention relates to drilling string pressure modulation valves, particularly those useful in combination with a drill string thruster used in conjunction with a drilling motor during drilling.

One way drilling a borehole can be accomplished is by circulation of fluid through a downhole motor which is operably connected to the drill bit. Such bottom hole assemblies have, at times in the past employed thrusters in an effort to improve drilling efficiency. The thruster is a telescoping tube arrangement which allows the drill bit to advance while the tubing string is supported in a rather stationary position at the surface. Ultimately, when the thruster has advanced its full stroke, or a notable portion thereof, the drill sting is lowered from the surface which causes the upper end of the thuster to slide down and therein close the thruster for the next stroke. When the drilling Kelley or the stand being drilled down by the top drive reaches the drill rig floor, circulation is interrupted and another piece of tubing is added to the string at the surface or the coiled tubing is further unspooled into the wellbore. This also causes the thruster to retract as a result of this procedure and the drilling procedure using the downhole motor begins once again.

In the past, depending on drilling conditions, fluid resistance in the downhole motor varies as a result of torque generated at the drill bit which is connected to the drilling motor. Fluctuations of pressure drop through the motor caused by the above noted bit torque change has in the past impeded the function of the thruster. What had occurred in the past was that the thruster responded to changes in pressure drop through the downhole motor instead of simply feeding out pipe as the drill bit advanced at at a constant weight on bit (WOB). The inability of the thruster to sense relatively constant pressures, regardless of the amount of work the drilling motor was required to do, caused instability to such thrusters to the point of

negating their functional operation and negatively impacting the drilling operation. What occurred was a pressure increase due to higher torque load on the motor as a result of changing drilling conditions. The higher or increased pressure was sensed at the thruster causing it to extend the telescoping portion out further which in turn increased the weight on the bit. Ultimately, with increasing weight on bit the motor torque was greater and the pressure sensed by the thruster was therein greater and drilling would cease as the thruster drove the motor in a stall condition where the drill bit is no longer turning.

In these past applications of the thruster, the weight on bit was a function of the pressure difference between inside and outside the thruster. The greater the difference the more force on the bit is exerted by the thruster. As a result, assemblies using thrusters with downhole motors in combination with drill bits have not been as efficient and useful as possible.

According to a preferred embodiment of the present invention there is provided a pressure modulation valve in the bottom-hole assembly between the thruster and the downhole motor to compensate for pressure increases as a result of changing drilling conditions which have in the past caused an increase in torque and as a result winched the WOB applied by the thruster. Ultimately, it is desired to make a thruster operable when used in conjunction with the drilling motor so that it can efficiently and reliably, without undue cycling or oscillation, feed out pipe in response to advancement of the drill bit during the drilling operation. Use of the pressure modulation valve facilitates a constant weight on the bit since variations in pressure drop in the circulating mud in the drilling motor do not affect the relative force exerted on the bit. With the modulation feature fully effective, these variations in pressure drop are compensated by the pressure modulation valve with the result being a facilitation of a constant weight on bit regardless of motor differential pressure.

A drill string pressure modulation valve is disclosed which is usable in combination with a downhole drilling motor and a drill string thruster to compensate for changes in pressure drop through the drilling motor which normally occur during

drilling. When conditions change during drilling, which in turn changes the pressure drop through the drilling motor, the drill string pressure modulation valve compensates for such changes to minimize the effect of such changes on the operation of the thruster and the resulting WOB created by the thruster. The modulation valve has a feature which allows it to find automatically a balanced preload condition for the main needle valve, the primary functional element within the modulation valve each time the rig pumps are turned off and then turned on. The modulation valve is fully self-contained, and is assembled as part of the bottom-hole assembly. The device senses the no-load pressure drop in the system and sets itself each time the rig pumps are turned on to compensate for any change in the no-load pressure drop experienced below the device which could be attributable to such things as motor wear, bit nozzle plugging, or changes in the flow rate. Accordingly, the hydraulic thrusting force remains constant over a wide range of drilling environments. As the drilling conditions change and the pressure drop in the downhole motor increases, the needle valve shifts to compensate for such additional pressure drop with a resultant small or no effect on the thruster and the resulting WOB created by the thuster located upstream of this modulation value.

Various embodiments of the present invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

Figure 1A-C illustrates a bottom-hole assembly in a sectional, elevation view showing the layout of the components, as well as a possible location for a measurement while drilling system which can be used in tandem with the apparatus.

Figure 2A-B is a sectional view of the drill string pressure modulation valve in the run-in position without the rig pump circulating.

Figure 3A-B is the view of Figure 2A-B with the pumps circulating, but the bit off bottom.

Figure 4A-B is the view of Figure 3A-B with the pumps running and the drill bit on bottom.

The drill string modulation valve of the present invention is illustrated in the bottom-hole assembly illustrated in Figure 1A-C. A drill or tubing string **32**, which can be rigid jointed pipe, reeled pipe or coiled tubing, supports a drill string thruster **34** and related bottom hole assembly elements. The thruster **34** has an outer housing **36** and an internal pipe **38**. The internal pipe **38** is reciprocally mounted within the outer housing **36** and extends as the drill bit **40** advances. The thruster **34** is responsive to pressure difference between internally of the bottom-hole assembly, referred to as **42**, and externally in an annulus around the assembly, referred to as **44**. The apparatus **A** is connected to the internal pipe **38**. Below the apparatus **A**, a measurement while drilling system can be inserted to supply data to the surface regarding formation conditions and/or the rotary orientation of the drill motor assembly **40**. The bottom-hole assembly of Figure 1A-C also indicates an upper stabilizer **46** and a lower stabilizer **48** between which is a drilling motor **50**. Optionally, to assist in drilling deviated wellbores, bent subs **52** and **54** can be employed in the bottom-hole assembly as well as, or alternatively, other desirable steering arrangements may be used.

This type of a bottom-hole assembly is typically used for deviated wellbores. The drilling motor **50** can be a progressive cavity type of a motor which is actuated by circulation from the surface through the drill string **32**. The weight or force on the drill bit **40** is determined by the pressure difference internally to the thruster **34** at point **42** and the annular pressure outside at point **44**. The drilling motor **50** is a variable resistance in this circuit in that the pressure drop across it is variable depending on the load imposed on the motor **50** by troque created at the drill bit **40**. For example, as drilling begins, the bit **40** causes an increase in load on the drilling motor **50** which increases the pressure drop between the drilling motor **50** and the annulus **44**. That increase in pressure drop raises the pressure difference across the thruster **34** (if the apparatus **A** is not used) by raising the pressure at point **42** with respect to the pressure at point **44**. As a result, the thruster **34** adds an

incremental force through the drilling motor **50** down to bit **40**. As additional weight is put on the bit **40**, the drilling motor **50** increasingly bogs down to the point where this cycle continues until the drill bit **40** stalls the motor **50** due to the extreme downward pressure that is brought to bear on the bit **40** from the ever increasing internal pressure at point **42** inside the thruster **34**. The thruster **34** instead of feeding out the internal pipe **38** in direct compensation for the advancement of the bit **40** instead is urged by the rise in pressure internally at point **42** to feed out the internal pipe **38** at a greater rate than the advancement of the bit **40**, thus adding the force on bit, which in turn finally stalls the drilling motor **50**. This had been the problem and the apparatus **A** of the present invention, when inserted in the bottom-hole assembly, as shown in Figure 1B, addresses this problem. The apparatus **A** acts as a compensation device, which, as its objective, keeps the pressure constant as possible at the internal point **42** of the thruster **34** despite variations in pressure drop that the drilling motor **50** created during drilling.

Referring now to Figure 2A and B, the apparatus **A** has a containment sub **1** which has a lower end **56** which is oriented toward the drilling motor **50**, and an upper end **58**, which is oriented toward the thruster **34**. In order to describe the operation of the apparatus, the pressure adjacent lower end **56** will be referred to as $\mathbf{P_1}$; the pressure adjacent the upper end will be referred to as $\mathbf{P_2}$; and the annulus pressure outside the containment sub **1** will be referred to as $\mathbf{P_3}$. Again, the objective is to keep $\mathbf{P_2}$ as constant as possible.

The assembly shown in Figure 2 starts near the upper end with lifting head **2** which is supported from the containment sub **1** at thread **60**. Attached to the lower end of the lifting head **2** is compressive pad **4**, which in turn is secured to a porous metal filter **7**. Below the porous metal filter **7**, liquid that gets through it flows through mud flow port **6** to a cavity **62** above delay valve piston **9**. Delay valve piston **9** is sealed at its periphery by seal **64** to divide the delay valve tube **8** into cavity **62** and cavity **66**. Delay valve spring **10** resides in cavity **66** and biases the delay valve piston **9** toward the porous metal filter **7**. A delay valve orifice assembly **12** is located at the lower end of the delay valve tube **8**. This is an orifice which, in

essence, regulates the displacement of clean fluid in cavity **66** into cavity **68**. Those skilled in the art will appreciate that movement of delay valve piston **9** downhole toward the lower end **56** will result in displacement of clean fluid, generally an oil, from cavity **66** through delay valve orifice block **11** into cavity **68** for ultimate displacement of piston valve **15**. Piston valve **15** is sealed internally in delay valve tube **8** by seal **70**. The piston valve **15** has a receptacle **72**, which includes a seal **74**, which ultimately straddles the low-pressure transfer tube **16**, as shown by comparing Figure **2A** to Figure **3A**. The low pressure transfer tube **16** extends to compensation tube body **20**. Inside of compensation tube body **20** is compensation spring **22**. Spring **22** bears on compensation piston **76** at one end and on the other end against modulating ram needle **27**. Needle **27** is sealed internally in the compensation tube body **20** by seal **78**. The compensating piston **76** is also sealed within the compensation tube body **20** by seal **80**. Both the compensating piston **76** and the needle **27** are movable within the compensating tube body **20** for reasons which will be described below. In effect, the piston **76** and the needle **27** define a cavity **82** within the compensation tube body **20**. The low pressure transfer tube **16** spans the entire cavity **82**, but is not in fluid communication with that cavity. A vent port **23** is in fluid communication with cavity **82**. The port **23** is in fluid communication with cartridge vent port **24**, which ultimately leads to transfer groove **25**, which in turn leads to the porous metal filter **26**. Accordingly, the pressure P_3 is communicated into the cavity **82**. Port **24** can be sized to make cavity **82** operate as a dampener on the movements of needle **27**. It can be directly connected to P_3 as shown or to an external or internal reservoir. The reservoir can have a floating piston with one side exposed to P_3 through the filter **26**. This layout can reduce potential plugging problems in filter **26**.

Referring now toward the lower end of the compensation tube body **20**, the needle **27** extends beyond an opening **84** and into the restrictor orifice **31**. The preferred components for the needle **27** and the restrictor orifice **31** is a carbide material. As illustrated in Figure 2B, the pressure at the inlet of the drilling motor **50**

(see Figure 1B) is the pressure **P_1**, which is also illustrated in Figure 2B. Normal flow to the motor **50** occurs from upper end **58** through passage **86** down around needle **27** and out lower end **56**.

In the position shown in Figure 2A, the low pressure transfer tube **16** communicates with cavity **88**, which in turn through openings or ports **17** communicates with cavity **90**. Those skilled in the art will appreciate that as long as the seals **74** do not straddle the top end of the low pressure transfer tube **16**, the pressure **P_1** at the lower end **56** communicates through low pressure transfer tube **16** through cavity **88** and into cavity **90** so that the pressure **P_1** acts on the area of the compensating piston **76** exposed to cavity **90**. A seal **92** retains the pressure **P_1** in cavity **90** while, at the same time, allowing the compensating piston **76** to move with respect to the low pressure transfer tube **16**. The low pressure transfer tube **16** is secured to the needle **27** and is placed in alignment with a longitudinal passage **94** in the needle **27**. A seal **96** separates the pressure **P_1**, which exists in passage **94** and in low pressure transfer tube **16**, from pressure **P_3**, which exists in cavity **82**. Seal **78** serves a similar purpose around the periphery of the needle **27**.

The significant components of the apparatus now having been described, its operation will be reviewed in more detail. Figures 2A-B reflect the apparatus **A** in the condition with the surface pumps turned off. In that condition, the spring **22** pushes the compensation piston **76** against delay valve tube **8** and, at the same time, pushes the needle **27** against the ledge formed by opening **84**. At the same time the delay valve spring **10** pushes the delay valve piston **9** against hydrostatic pressures applied through the upper end **58** through the porous metal filter **7** and mud flow port **6**. At this point with no flow, **P_1=P_2** and the delay valve piston **9** is in fluid pressure balance.

When the surface pumps are turned on, the first objective of the apparatus **A** of the present invention is to obtain a preload force on the needle **27** which actually compensates for the mechanical condition of the motor **50** and any other variables downhole which have affected the pressure drop experienced in the region of the drilling motor **50** and the bottom-hole assembly since the last time the pumps were operated from the surface. The desired preload acts to put a force on the needle **27**

which will prevent it from rising on increasing pressure P_1 until a predetermined level is exceeded. Stated in general terms, the pressure P_2 is maintained at a desirably a steady level as possible by modulation of the position of needle **27** responsive to fluctuations in pressure P_1. Variations in pressure P_1 will occur as a result of the drilling activity being conducted with bit **40**. Accordingly, with the surface pumps turned on and the bit **40** off of bottom, meaning that there is no drilling going on, the pressure P_2 increases with respect to pressure P_3 as circulation is established. When this occurs, the pressure P_1 also increases with respect to pressure P_3. As previously stated, cavity **82** communicates with pressure P_3 through the porous metal filter **26**. By proper configuration of the compensating piston **76**, the pressure P_1, which exceeds the pressure P_3, communicates through the low pressure transfer tube **16** into cavity **88** through ports **17** and into cavity **90**, and onto the top of compensating piston **76**. Ultimately, an imbalance of forces occurs on compensating piston **76** due to pressure P_1 in cavity **90** and P_3 in cavity **82** which causes piston **76** to compress the compensation spring **22**. The compensating piston **76** is designed to complete its movement and reach an equilibrium position before the piston valve **15** moves downward sufficiently to bring the seal **74** over the upper end of the low pressure transfer tube **16**. Figures 3A and B show the conclusion of all the movements when the pumps on the surface are turned on and the bit **40** is off of bottom. However, the movement occurs sequentially so that the piston **76** finds its preload position, shown in Figure 3B, before movement of piston valve **15** occurs. Movement of piston valve **15** occurs as the pressure P_2 ultimately communicates with cavity **62**, as described previously. The fluids in the well, which have been passed through the porous metal filter **7** push on the delay valve piston **9** and ultimately the delay valve spring **10** is compressed. As previously stated, the cavity **66** is filled with a clean oil which is ultimately forced through the orifice assembly **12** into cavity **68** by movement of delay valve piston **9**. The orifice assembly **12** is designed to provide a sufficient time delay, generally 1-2 minutes, so that the compensating piston **76** can find its steady state position. Those skilled in the art will appreciate that when the surface pumps are turned on and flow is

initiated, it takes a little time for the circulating system to stabilize. Thus, one of the desirable functions of the apparatus **A** is that the low pressure transfer tube **16** is not capped by the piston valve **15** by virtue of seal **74** until the compensating piston **76** has found its desirable position shown in Figure 3B. In the position shown in Figure 3B, the forces on the compensating piston **76** have reached equilibrium. Thus, the pressure P_3 acting on the bottom of compensating piston **76** in conjunction with the force of compensation spring **22** becomes balanced with the pressure P_1 that is acting in the now enlarged cavity **90**. Ultimately, enough clean fluid passes through the delay valve orifice assembly **12** to urge the piston valve **15** downwardly to the position shown in Figure 3A such that the seal **74** straddles the low pressure transfer tube **16**. As soon as this occurs, the compensation piston **76** is in effect isolated from further fluctuations of the pressure P_1. In effect, the pressure at the lower end **56** can no longer communicate with the top end of the compensating piston **76** because the piston valve **15** has cutoff the access to cavity **90** by capping off the low pressure transfer tube **16**.

After having attained the position shown in Figures 3A and B, the drilling with bit **40** begins. This puts an additional load on the motor **50** which in turn raises the pressure P_1. As the pressure P_1 rises, the needle **27** has a profile, which in turn decreases the pressure drop across the restrictor orifice **31** as the needle **27** moves upwardly. Due to the profiles of needle **27** as the needle moves up the pressure drop change per unit of linear movement is increased. The spring **22** resists upward movement of the modulation ram needle **27**. At this point in time when the bit **40** contacts the bottom of the hole, the compensating piston **76** is immobilized against upward movement because the piston valve **15** has capped off the pressure P_1 from communicating with cavity **90**. Since P_2 is always greater than P_1 due to frictional losses and the pressure drop across the orifice **31**, the pressure in cavity **68**, which is P_2, keeps the piston valve **15** firmly bottomed in the delay valve tube **8**. As previously stated, the seal **70** prevents the pressure P_2, which is in cavity **68** in Figure 4A from getting into cavity **90**. Accordingly, the compensating piston **76** now is in a position where it supports the spring **22** with a given preload force on the

needle 27. As the motor 50 takes a greater pressure drop, which tends to increase P_1, the upward forces on needle 27 eventually exceed the downward forces on needle 27. The downward forces on needle 27 comprise the pressure P_3 acting on top of the needle 27 in cavity 82 in combination with the preload force from spring 22. Thus, an increase in the pressure P_1 which exceeds P_3 backs the needle 27 out of the orifice 31 removing some of the pressure losses that had been previously taken across the orifice 31. Thus, the increase in pressure drop at the motor 50 is compensated for by a decrease in pressure drop at the orifice 31 with the net result being that very little, if any, pressure change occurs as P_2 remains nearly steady. In other words, the system pressure drops upstream of the upper end 58 remains steady and all that desirably occurs is an increase in pressure drop through the motor 50 compensated for by a corresponding decrease in pressure drop across the restrictor orifice 31 with the net result that the thruster 34 sees little, if any, pressure change as indicated by the symbol P_2.

When the pumps are again turned off at the surface, the apparatus A quickly resets itself. As the pumps are turned off at the surface P_2 decreases, thus reducing the pressure in cavity 62. A check valve 13 allows flow into cavity 66 from cavity 68. Accordingly, when the spring 10 pushes the piston 9 upwardly, it draws fluid through the check valve 13, which in turn draws fluid out of cavity 68. The drawing of fluid out of cavity 68 brings up the piston valve 15 and ultimately takes the seal 74 off of the top of the low pressure transfer tube 16. When this occurs, P_1 can then communicate through the low pressure transfer tube 16 and into cavity 90 as previously described. Ultimately, with no fluid circulating, P_3 will be equal to P_1 and the spring 22 will bias the compensating piston 76 back to its original position shown in Figure 2B. Therefore, the next time the surface pumps are started, the process will repeat itself as the compensating piston 76 seeks a new equilibrium position fully compensating for any changes in condition in the circulating system from the drilling motor 50 down to the bit 40.

Those skilled in the art will appreciate that the configuration of the compensating piston 76 is selected in combination with a particular spring rate for

the compensating spring **22** to deliver a preload force on the needle **27** within a limited range. Too little preload is undesirable in the sense that minor pressure fluctuations in P_1 during drilling will cause undue oscillation of the needle **27**. On the other hand, if the preload force is too great, the system becomes too insensitive to changes in P_1, thus adversely affecting the operation of the thruster **34** and if extreme enough causing the thruster **34** to load the bit **40** to the extent that the motor **50** will bog down and stall. Thus, depending on the parameters of the drilling motor **50** and the bit **40**, the configurations of the compensating piston **76** and spring **22**, as well as the profile of the needle **27** can be varied to obtain the desired performance characteristics. Similarly, the orifice assembly **12** can be designed to provide the necessary delay in the capping of the low pressure transfer tube **16** to allow the system to stabilize before the low pressure transfer tube **16** is capped. This, in turn, allows the compensating piston **76** to seek its neutral or steady state position before its position is immobilized as the piston valve **15** caps off the low pressure transfer tube **16**. In essence, what is created is a combination spring and damper acting on the needle **27**. The spring is the compensation spring **22**, while the damper is the cavity **82** which varies in volume as fluid is either pushed out or is sucked in through port **24** or the porous metal filter **26** which can act as an orifice in the damper system.

Those skilled in the art will now appreciate that the apparatus **A** provides several important benefits. It is self-contained and it is a portion of the bottom-hole assembly. Each time the surface pumps are turned on the compensating feature adjusts the preload on the needle **27** to account for variations within the circulating system.. Once in operation during drilling, the system acts to smooth out pressure fluctuations caused by changes in the drilling activity so that the pressure fluctuations are isolated as much as possible from the thruster **34**. With these features in place, drilling can occur using a downhole motor. Downhole motors are desirable when using coiled tubing or when the string, even though it is rigid tubing, is sufficiently long and flexible to the extent that a downhole motor becomes

advantageous. The system using the apparatus **A** resets quickly using the check valve feature and stands ready for a repetition of the process the next time the surface pumps are turned on.

It should be noted that the normal pressure drop across the orifice **31** with the bit **40** off of bottom is approximately 400 (2760 kPa) or 500 psi (3450 kPa) or better stated should equal or slightly exceed the expected maximum drilling pressure drop expected to be generated by the drilling motor at full load conditions, in the preferred embodiment. That pressure drop is reduced during operation as the drilling motor **50** resistance increases which causes the needle **27** to compensate by backing out of the orifice **31**, thus reducing the pressure drop. It should also be noted that the amount of preload provided by the compensation spring **22** needs to be moderated so as not to be excessive. Excessive preload on the needle **27** reduces the sensitivity of the apparatus **A** in that it requires the pressure P_1 to rise to a higher level prior to the apparatus reacting by moving the needle **27** against the spring **22**. Thus, a higher preload on spring **22** also reduces sensitivity. Those skilled in the art can use known techniques for adjusting the variables of preload and needle profile within an orifice **31** to obtain not only the desired pressure compensation result but the appropriate first, second, and higher order responses of the control system so that a stable operation of the modulation ram needle **27** in orifice **31** is achieved.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made.

CLAIMS

1. A downhole drilling assembly, comprising:

a downhole motor supported on tubing;

a bit driven by said motor;

an MWD package which can contain both directional and a full complement of formation and seismic logging sensors;

a drill string thruster mounted to said tubing which extends in length for application of a desired weight on said bit;

a compensating device to compensate for pressure change in said tubing or drill string caused by said bit or said motor to allow proper functioning of said thruster.

2. The assembly of claim 1, wherein:

said compensating device further comprises a variable orifice adjacent said thruster.

3. The assembly of claim 2, wherein:

said variable orifice comprises a movable member biased in a direction where the orifice is made smaller.

4. The assembly of claim 3, further comprising:

a preload adjustment acting on said movable member, said preload adjustment responsive to applied pressure to said compensating device.

5. The assembly of claim 4, wherein:

said preload adjustment senses the pressure difference between pressure adjacent said variable orifice (P_1) and an annulus pressure outside said compensating device (P_3);

said preload adjustment comprises a first piston movable responsive to the pressure difference of P_1-P_3.

6. The assembly of claim 5, further comprising:

a locking device to prevent further movement of said first piston after said first piston reaches equilibrium under a pressure difference of P_1-P_3 with said bit off the hole bottom, thereby locking in a predetermined preload force on said movable member.

7. The assembly of claim 6, wherein:

P_1 represents the pressure required to flow through said motor and said bit;

said locking device isolates one side of said first piston from pressure P_1 after it reaches an equilibrium position due to pressure P_1 acting on one side and pressure P_3 acting on the other side.

8. The assembly of claim 7, wherein:

said locking device comprises a second piston whose movement to a position where said first piston's movement is locked is delayed to allow said first piston time to reach an equilibrium position based on P_1-P_3 with said bit off the hole bottom.

9. The assembly of claim 8, wherein:

said preload adjustment comprises a spring between said first piston and said movable member, said spring disposed in a sealed cavity exposed to said annulus pressure (P_3) and to one side of both said first piston and said movable member.

10. The assembly of claim 9, further comprising:

a tube sealingly extending into a path through said movable member, said tube sealingly extending through said chamber and through said first piston to communicate pressure P_1 to a second side of said piston opposite said chamber.

11. The assembly of claim 10, wherein:

said second piston closes off pressure P_1 from said second side of said first piston by sealingly covering an end of said tube extending through said first piston.

12. The assembly of claim 11, wherein:

said second piston is responsive to a pressure build-up at an inlet to said compensation device (P_2) to move to seal off said tube.

13. The assembly of claim 12, further comprising:

a third piston exposed to pressure P_2 which displaces fluid through an orifice to said second piston to effect a time delay of movement of said second piston and, as a result, the sealing of said tube until said first piston reaches equilibrium when said first piston is exposed to a pressure difference of P_1-P_3 with said bit off the bottom.

14. The assembly of claim 9, wherein:

said spring with said preload from movement of said first piston allows movement of said movable member in response to fluctuation of P_1 to change the orifice size so as to keep pressure at an inlet to said compensation device P_2 nearly steady.

15. The assembly of claim 14, wherein:

said cavity communicates to said annulus through a restricting opening so as to allow said cavity and the fluid therein to act as a fluid dampener in conjunction with said spring to regulate compensatory movements of said movable member responsive to changes in P_1.

16. A bottomhole drilling assembly, comprising:

a fluid-operated motor driving a bit;

an extendable thruster which is pressure-responsive to control weight on the bit during drilling;

a compensator adjacent said thruster to compensate for pressure changes created by operation of said motor and said bit.

17. The assembly of claim 16, wherein:

said compensator comprises a member movable to create a variable orifice responsive to pressure changes induced by operation of said motor and said bit.

18. The assembly of claim 17, further comprising:

an automatic preload assembly to control the amount of preload bias on said member responsive to an internal pressure (P_1) below said variable orifice due to flow through said motor and bit, and an outside pressure (P_3) in the surrounding annular space outside the bottomhole drilling assembly, both pressures sensed with said motor turning and said bit off the well bottom.

19. The assembly of claim 18, further comprising:

a lock system to lock in said preload force after said preload assembly has reached its equilibrium position responsive to said pressure difference P_3-P_1.

20. The assembly of claim 19, wherein said preload assembly further comprises:

a movable first piston having a first side defining, in conjunction with said movable member, a cavity exposed to said annular space and pressure P_3 and having a spring between said first piston and said movable member;

said first piston having a second side selectively exposed to said pressure P_1 until said lock system isolates P_1 from said second side of said first piston.

21. The assembly of claim 20, wherein:

said cavity has a restriction in its communication with said annulus pressure P_3 so as to allow the fluid therein to dampen movement of said movable member in conjunction with the bias to said movable member applied by said spring.

22. The assembly of claim 21, wherein:

said movable member has a passage which communicates the pressure P_1 through a tube to a second side of said first movable piston, said lock system selectively covering an end of said tube to isolate said second side of said first piston from the pressure P_1.

23. The assembly of claim 22, wherein:

said lock system comprises a second piston which moves in sealing contact with said end of said tube after a delay long enough to allow said first piston to reach equilibrium when exposed to a pressure differential of P_1-P_3 when said bit is off the well bottom.

24. The assembly of claim 23, wherein:

said delay is accomplished by a third piston with one side responsive to pressure adjacent said thruster (P_2), said third piston displacing fluid through an orifice to said second piston at a controlled rate such that movement of said second piston and closing off said tube is delayed until said first piston is in said equilibrium position.

25. A downhole drilling assembly substantially as hereinbefore described and with reference to the accompanying drawings.

The Patent Office

Application No:	GB 9818238.9	**Examiner:**	Dr. Robert Fender
Claims searched:	1-25	**Date of search:**	23 October 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): E1F: FCA

Int Cl (Ed.6): E21B 44/00

Other: Online : WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	US 5679894	(BAKER HUGHES INCORPORATED)	-
A	US 4901806	(DRILEX SYSTEMS, INC)	-
A	US 4768598	(BAKER HUGHES INCORPORATED)	-
A	US 4660656	(AMOCO CORPORATION)	-
A	US 4615401	(SMITH INTERNATIONAL) see figures 1-3	-

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